probably killed the adult insect before oviposition, although adult feeding was not greatly reduced. DDT at 2 pounds or Guthion at 1 pound per 100 gallons beginning at emergence and continued at 4-day intervals for approximately 1 month should give a high degree of control of this insect, if special care is taken to direct the spray at the lower part of the stem and the soil. Guthion is not available for commercial use on sweet corn at present.

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Biology of the Convergent Lady Beetle When Fed a Spotted Alfalfa Aphid Diet[1]

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ABSTRACT

Laboratory studies on the biology of the convergent lady beetle (*Hippodamia convergens* G.-M.), when fed spotted alfalfa aphids (*Therioaphis maculata* (Buckton)), showed that the incubation period of the egg averaged 2.0 days, the larval stage 7.6 days, the pupal stage 4.1 days and the period from egg to adult 13.8 days. There were four larval instars. Daily consumption of aphids per instar was in direct arithmetical proportion and total consumption in direct geometrical proportion to the larval instar. When reared in the laboratory adult males lived longest on a diet of 60 and females on 90 aphids per day, whereas field-collected adults of both sexes lived longest on 30 aphids per day. Most laboratory-reared adults lived longer than field-collected adults. Females from both sources generally lived longer than males. The length of the immature stages was shorter and daily aphid consumption higher than when other aphids were used as the diet.

Since the spotted alfalfa aphid (*Therioaphis maculata* (Buckton)) has been found in Arizona, the convergent lady beetle (*Hippodamia convergens* G.-M.) has increased in its importance as a predator of this pest. The beetle is most abundant in the spring and more effective during that period than any other predator studied in Arizona.

Several workers in other States (Bieberdorf & Bryan 1956, Davis *et al.* 1957, Dickson *et al.* 1955, Smith & Hagen 1956, and Tuttle 1956) have indicated the convergent lady beetle's abundance and feeding efficacy over other aphid predators. Recently it has been found to consume twice as many spotted alfalfa aphids as does, its nearest competitor, *Collops vittatus* (Say), (Nielson & Henderson 1959).

In the summer of 1958 a laboratory study was made of the biology of this lady beetle when fed a diet of spotted alfalfa aphids. This study was started in Tempe, Arizona, and completed in Mesa. Special emphasis was placed on aphid consumption by the larvae and on the longevity of adults. Comparative data for other aphid species reported in the literature are also included.

LENGTH OF IMMATURE STAGES.—Beetles were collected in the field, and pairs of adults were confined in plastic containers for mating. After the eggs hatched the larvae were placed individually in 1-×5-inch glass tubes stoppered with cork disks, and were fed spotted alfalfa aphids daily until the end of the last instar. The lengths of the egg, larval, and pupal stages are given in table 1. About 14 days were required for the insect to complete its development.

APHID CONSUMPTION.—Records were kept on the number of spotted alfalfa aphids consumed by the larvae each day. The results are summarized in table 2. The data indicate that the daily consumption per instar was in direct arithmetical proportion and the total consumption in direct geometrical proportion to the instar. By analogy, these data may lend support to hypothetical growth curves for other sap-sucking insects. Such data are difficult to obtain, owing to lack of techniques for accurate

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Table 1.—Length, in days, of immature stages of the convergent lady beetle in the laboratory, June 13–27, 1958, Tempe, Arizona.[a]

STAGE	RANGE	AVERAGE
Egg	2–2	2.0
First instar	1–2	1.3
Second instar	1–2	1.3
Third instar	1–3	1.8
Fourth instar	3–4	3.3
Pupa	3–4	4.1
Total	11–18	13.8

[a] 45 records for all stages except egg, 50.

Table 2.—Consumption of spotted alfalfa aphids by larval instars of the convergent lady beetle, June 16–27, 1958, Tempe, Arizona.

INSTAR	NO. OF APHIDS PER BEETLE	
	Daily	Total
First	16.9	22.9
Second	23.6	29.9
Third	44.3	78.7
Fourth	63.1	206.2

measurement of amounts of sap consumed by these insects.

ADULT LONGEVITY.—Information on adult longevity of the convergent lady beetle was obtained from laboratory-reared and field-collected adults. Twenty-five adult beetles of each sex from each source were placed individually in glass tubes similar to those used for the larvae, and arranged in groups of five. The first group received no aphids and each of the other groups received a different number of aphids per day. The longevity of each group is shown in table 3. Males reared in the laboratory lived longest on 60 aphids and females on 90 aphids per day. The loss of one female after the 22nd day shortened the overall longevity of the 60-aphid-per-day group. Both sexes from the field lived longest on a diet of 30 aphids per day. In general laboratory-reared aphids lived longer than those from the field. Females from both sources generally lived longer than males. The adults that were starved lived only a few days.

Table 3.—Longevity, in days, of adult laboratory-reared and field-collected convergent lady beetles after feeding on a constant diet of given numbers of spotted alfalfa aphids, June 26 to August 18, 1958, Mesa, Arizona.

NO. OF APHIDS FED DAILY	MALES		FEMALES	
	Laboratory	Field	Laboratory	Field
120	23.0	14.0	26.3	22.8
90	31.2	23.8	32.0	6.8
60	38.8	20.6	27.2[a]	27.8
30	17.6	29.2	27.8	33.6
0	2.0	1.0	2.2	3.2

[a] One lost on 22nd day.

The greater longevity of laboratory-reared individuals indicated that the adults from the field were at least 7 days old at the time they were collected. Moreover, the greater food requirements for the laboratory-reared adults indicate prior feeding by the field-collected group.

COMPARATIVE DATA ON OTHER APHID SPECIES.—The value of the convergent lady beetle as a predator of other aphid species has been recognized by other workers. Table 4 shows the length of the immature stages and consump-

Table 4.—Length of immature stages and consumption of various aphid species by the convergent lady beetle in different States, as reported by several workers.

STATE AND SPECIES	LITERATURE SOURCE	LENGTH OF IMMATURE STAGES (DAYS)			NUMBER OF APHIDS CONSUMED	
					Average per	
		Egg	Larva	Pupa	Larval Stage	Adult per Day
Arizona						
Therioaphis maculata	Nielson & Henderson (1959)	—	—	—	—	97
	Present paper	2	8	4	—	—
California						
Macrosiphum pisi	Campbell (1926)	—	—	—	200	20
Phorodon humuli (Schr.)	Clausen (1915)	5	16	7	349	56
Colorado						
Chaitophorus negundinis (Thomas) *Macrosiphum gaurae* Williams *Macrosiphum rosae* (L.) *Prociphilus fraxinifolii* (Riley)	Palmer (1914)	3	14	5	433	67
Florida						
Aphis spiraecola Patch	Miller & Thompson (1927)	4	11	5	—	—
	Thompson (1928)	—	—	—	616	87
Minnesota						
Toxoptera graminum (Rond.)	Stehr (1930)	—	—	—	124	46
Oregon						
Macrosiphum pisi	Rockwood (1952)	—	—	—	207	10

tion of various aphid species. All the studies were conducted while the beetles were in captivity. The shortest length of life was in Arizona, and the longest in California. The differences appear to be due to environment and food. Daily aphid consumption also varied considerably. It was lowest in Oregon and California with *Macrosiphum pisi* (Harris), and highest in Arizona with *Therioaphis maculata*.

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Distribution and Sorption of Liquid Fumigants Applied to Wheat by Recirculation[1]

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ABSTRACT

Laboratory fumigation experiments with wheat at 12.2% moisture and 77° F. were conducted in recirculators using a liquid formulation of 76.5% carbon tetrachloride (CCl_4), 3.5% ethylene dibromide (EDB), 10% carbon disulfide (CS_2), and 10% ethylene dichloride (EDC), by weight, to study the sorption and vertical distribution of each component. Gas samples were taken at five levels and five times during fumigation and were analyzed by mass spectrometry and by thermal conductivity. A small amount of EDB reached the bottom, but nearly all the EDB apparently was sorbed in the upper levels during the 30 minutes of recirculation. The other components were fairly evenly distributed but showed a slight tendency to settle downward during the longer exposures. Selective sorption occurred and the decreasing order of sorption was EDB, EDC, CS_2, CCl_4. Based on pounds of fumigant per 1000 cubic feet, the average composition in gas samples taken from interstitial space after 24 hours of exposure was 86.56% CCl_4, 0.00% EDB, 7.15% CS_2, 1.26% EDC, and 5.24% CO_2. Of the total formulation about 65% and 85% were sorbed during ½ and 24 hours, respectively.

The recirculation method of fumigating bulk-stored grain offers many advantages over the conventional methods, which utilize the forces of nature to distribute the fumigant vapors in a grain mass. Phillips (1957) was among the first in this country to report the practicality of applying liquid fumigants by recirculation. Considerable information is available concerning the insecticidal performance of liquid fumigants, but relatively little is known about the distribution and sorption of each chemical component. Kenaga (1956) reported on the gravity distribution of the components of liquid fumigants in a column of grain. The present paper presents the results of experiments conducted to determine the distribution and sorption of four chemical compounds in a liquid formulation when applied by the recirculation method.

METHODS AND MATERIALS.—Serafume®[4], a fumigant formulation containing 76.5% carbon tetrachloride (CCl_4), 3.5% ethylene dibromide (EDB), 10% carbon disulfide (CS_2), and 10% ethylene dichloride (EDC), by weight, was selected because it provided an opportunity to observe four of the commonly used components of commerical mixtures in one experiment. Duplicate fumigations were conducted on two different dates, making a total of four replicates. The average fumigation temperature was 77° F. (74° to 80°).

Each recirculator (Fig. 1) was 6 feet tall and 8 inches in diameter and was filled with 100 pounds of Hard Red Winter Wheat having a moisture content of 12.2%. The total volume of each recirculator, including the blower and duct, was 2.47 cubic feet. Copper gas sampling tubes were located at the 3-, 18-, 36-, 54-, and 72-inch levels, from the top downward. After filling the recirculators with wheat and sealing them with plastic tape, a neoprene stopper was removed from the top of each and the fumi-

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[3] One of the field stations of the Stored-Product Insects Section, Market Quality Research Division, U. S. Department of Agriculture.

[4] Trademark of the Dow Chemical Company. The use of trade names in this paper is for identification purposes only and does not constitute an endorsement of the products by the United States Department of Agriculture.